Stonehenge Reprise: Updating a "Neolithic Computer"

By
Vincent H. Malmström
Emeritus Professor of Geography
Dartmouth College
Hanover, New Hampshire
03755

I met Gerald Hawkins only once; as a member of the prestigious Cosmos Club of Washington, D.C., he had come down from Boston expressly to attend my lecture on the origins of the Maya calendar in March 1981; naturally, I was quite flattered by his presence.

Under the circumstances, our meeting was necessarily brief, but cordial. He wished me well in my further research and gave me a friendly admonition. He advised me that anyone working in archaeoastronomy could expect a lot of 'flak' from both the archaeologists and the cultural historians. The former, he explained, expected to find "all the answers digging in their holes", whereas the latter appeared to believe that "it was they alone who were capable of understanding the motives and thought processes of preliterate peoples". As for himself, he felt that the only "hard evidence" would ultimately be found in astronomy, a motion that I enthusiastically seconded.

With respect to his admonition, I admitted that I had already run afoul of the dean of Maya archaeologists, having accused him of doing a terrible disservice to his discipline in 1935 when he revised his notion of the beginning date of the Maya calendar from August 13 to August 11. At the time that he did so, he delivered an additional dictum that many of his disciples have either overlooked or chosen to ignore, namely not to expect Maya dates ever to coincide with actual celestial events because the Maya, he said, were not *astronomers but astrologers*. Nevertheless, right up to the present time, we find some of his misguided fraternity still trying to hopelessly equate his unfortunate 'revision' with the facts of the real world!

Ironically, a couple of generations later, when I found myself questioning some of the data that Hawkins had used in his ground breaking study in archaeoastronomy titled “Stonehenge Decoded”, it was as though our brief encounter that evening had come full circle – but to an surprising and, sad to say, rather disappointing conclusion.

Unlike the Mayan archaeologist, Hawkins could hardly be chastised. His problem was not a “change of heart”, but rather a lack of astronomical data that was of sufficient age and accuracy to corroborate his work on Stonehenge. Unfortunately, the monumental “Canon of Eclipses” published by Count Theodor von Oppolzer in 1887 went back only as far as 1207 BCE, so Hawkins had to rely instead on what was then a recent work (published in 1945) by a Dutch astronomer named Van den Bergh. Although it extended Oppolzer’s survey of eclipses to 1600 BCE, what Hawkins was really looking for was data that reached at least four centuries farther into the past.

From the list of eclipse events that Hawkins had selected from Van den Bergh to support his thesis, he casually assumed that “Not more than half {of those eclipses} were visible from Stonehenge” (page 139); in point of fact, only one of the solar eclipses could have been seen, even briefly, from there. Because solar eclipses are less numerous and more restricted in geographic scope than lunar eclipses, this was not necessarily a damning indictment of his work, but it certainly did nothing to strengthen his hypothesis. Lunar eclipses, on the other hand, are usually visible over almost half of the globe, but were much more feared and misunderstood by early peoples. (Editor’s note: When a solar eclipse takes place, the disk of the moon can usually be clearly seen to have moved in front of the sun, but when a lunar eclipse occurs, there doesn’t seem to be any apparent cause. That it was the shadow of the Earth itself that darkened the moon was quite unthinkable to most early sky-watchers.) Fortunately, all of the 23 lunar eclipses in Hawkins’ sample were at least visible from Stonehenge. Ten of the latter he had assumed had been preceded by a mid-winter moonrise over the Heel stone, four he expected to follow a similar moonrise over stone D, and nine others he reckoned to have taken place when the winter moon rose over stone F. Of the first group, all but the two July events did come close to having coincided with moonrise over the Heel stone, ranging in azimuth from about 50° to 55°. (The two July events in his list bracketed an azimuth of 127°, close to where the moon rises at the lunar minimum.) The four lunar eclipses which he anticipated would have occurred after a winter moonrise over stone D (azimuth 42º) rose at azimuths ranging from about 81º to 94º, while the nine that he expected to have taken place in connection with moonrises over stone F (azimuth 58º) rose at azimuths that varied between about 83º and 100º. Thus, while all of the eclipses in the latter two groups did take place relatively close to the equinoxes, as he had said they would, his predictions of where the moon would rise on these occasions turned out to be totally in error.

Although Hawkins confidently concluded that "Stonehenge scored 100 percent in predicting winter and/or summer eclipses" (page 178), it is obvious from the data he had available to him that the 'invisible' solar events lent no support to his theory whatsoever. On the other hand, his lunar data proved accurate in eight out of ten instances when he anticipated a moonrise over the Heel stone, but ended up rather consistently yielding azimuths close to the equinoxes (i.e., ca. 80º to 100º) whenever he had anticipated moonrises over either stone D, at an azimuth of ca. 42º, or stone F. at an azimuth of ca. 60º. (Incidentally, this angular range equates almost exactly to the distance between the two so-called Aubrey holes that bracket the rising and setting azimuths of the sun at the equinoxes, and thus limit the predicted date of such eclipses to within about 1 to 2 days.)

However, the crux of Hawkins' claim to having "decoded Stonehenge" rests primarily on his identification of the function of the so-called Aubrey holes themselves, a series of equally spaced depressions that encircle the monument just inside its outermost ditch. These, he maintained, had served as a counting mechanism to predict eclipses, and for which he makes a very credible argument that their number – 56 – represents the sum of two cycles of nineteen years plus one cycle of eighteen years, which, if divided by three, would almost exactly approximate the length of time between two lunar maxima or minima. (The value thus obtained -- 18.67 years – is only .06 of a year, i.e., ca. 22 days, longer than the actual interval itself.) In other words, because the builders of Stonehenge, in common with many, if not most, other early peoples seem to have had either an ignorance of or an aversion to fractions, they chose to work instead exclusively with integers until they obtained a suitable match between two given values. (One illustration from the Maya will suffice to make the point; they knew that the time between two full moons was not 29 days, but neither was it 30; however, when exactly 4,400 days had gone by, they found that their count of full moons reached an even total of 149; through such a process they obtained a value which is almost exactly the same as that employed by modern astronomers.) On the other hand, when the Megalithic sky-watchers of western Europe had measured the time between two full moons, rather than trying to describe it as 29.53 days, they settled for thinking of it instead in terms of two lunations (i.e., full moons) equaling 59 days. They found that they could overlook the extra .06 of a day for more than a year before they had to correct their count by adding another day. That was certainly a lot simpler than waiting for over 12 years -- as the Maya had to -- in order to obtain a precise correspondence between the integers that defined both lunations and days.

Hawkins hypothesized that each year the Megalithic builders of Stonehenge had systematically moved stones of different colors around the Aubrey holes to predict eclipses, for example, by using black for solar events and white for lunar events. (Editor's note: Naturally, if this scenario is accurate, the 'general public' would have to have been excluded from the central precinct of the monument, lest some unknowledgeable 'country bumpkin' might disturb the count and put more that half a century of 'records' in jeopardy.) Hawkins argued that with six such stones, spaced at intervals of 9, 9, and 10 Aubrey holes from each other, it was possible to accurately predict eclipses of both the sun and the moon at the solstices and the equinoxes for hundreds of years. Thus, for his experiment, he 'positioned' black stones at Aubrey holes 9, 28,and 47, and white stones at Aubrey holes 10, 38, and 56. Whenever a stone of either color reached Aubrey hole 56 (located just in front of the Heel stone), he said that an eclipse would take place.

The prime mover in his theory was the "winter moon" – the moon that rose closest to the winter solstice. If that rose over the Heel Stone, he said that an eclipse would occur during the months of the solstices. In our present calendar these occur on or about December and June 22nd, but during the period Hawkins was examining (-1600 BCE), they would have taken place some 15 days later, according to the Julian calendar: the winter solstice on January 6th and the summer solstice on July 5th.

But the solstices mark only the mid-points between the lunar maxima and minima, so when the winter moon 'strays' to the north side of the Heel Stone and rises over stone D instead, he said that an eclipse could be expected in the months of the equinoxes – meaning today, close to March 20 in the spring and September 22 in the autumn, or for Hawkins' test period, April 4th in the spring and October 7th in the autumn. By the same token, if the winter moon ‘strays’ to the south of the Heel Stone and rises over stone F instead, the eclipse will again take place during one of the equinox months. Thus, Hawkins argued that by charting the moon’s behavior in mid-winter it was possible to predict the eclipse pattern, at least for that year’s solsticial and equinoctial months, a conclusion that our analysis has already shown to be faulty.

The Challenge and The Response

One can only wonder if Hawkins, a professional astronomer, really understood the magnitude of the task he had set for himself. Did he have any way of knowing how many eclipses, both lunar and solar, he might have to contend with that would be visible from Stonehenge in any given 56-year period of time? And, if so, could moving six black and white stones one hole each year around the circumference of the circle actually have forecast their occurrence in a timely enough fashion to have warned the local populace of an impending eclipse?

Unfortunately, as we have already explained, when Hawkins was formulating his theory, the data available to him was meager at best and questionable to say the worst. Had the eclipses tabulated by Van den Bergh not carried “B.C.” dates on them, one would have thought they might have been observed by Dutch navigators in the early Middle Ages, as they plied their way between Amsterdam and the East Indies, for the bulk of them seem to have come from the southerly latitudes of the Indian and Pacific Oceans. In any case, from the comforting position of hind-sight, aided and abetted by the ‘iron clad’ evidence provided by the NASA eclipse website, we now know that the challenge faced by Hawkins was strikingly similar to that confronted by the generation that fought the Battle of Britain -- (which he had himself experienced as a child) – sending up a handful of Spitfires (his colored stones) to cope with seemingly unending waves of Luftwaffe bombers (the continuous chain of eclipses). Our question then is, did Hawkins really have the means to carry out the strategy he had in mind, given the minimalist resources he was assigning to the task?

In order for Hawkins to initiate his test of the “Stonehenge computer”, he had first to establish the beginning date of one of the 56-year eclipse cycles he hoped to replicate. He found that one such year had been -1610 BCE, but because Van den Bergh’s data stopped short at -1600, Hawkins had to start his count one cycle later, in -1554 instead. He admits that he didn't know in which direction the Stonehenge astronomer would have moved the stones around the circle of the Aubrey holes, and his book reveals his ambivalence by a diagram showing them with anticlockwise arrows on page 142, while in the appendix (page 179) he has another diagram showing them attached to clockwise arrows. However, it didn't take him long to realize that his theory could only work if the stones were moved one year at a time in an *anticlockwise* direction – in other words, in "the path of the sun", which the present author had earlier found seemed to have made the most sense to other early sky-watchers elsewhere in the world. (For example, American Indian civilizations all thought of north as being on the 'right hand" and south as having been on the "left".)

What Hawkins could not have known, but, which we since have learned, is that in the 56-year period he had chosen to investigate, no fewer than twenty solar eclipses and twenty-three lunar eclipses took place. This meant that during the years -1554 to -1498, Stonehenge would, on average, experience an eclipse every 475 days, or 16 months. That Hawkins (or any early Stonehenge sky-watcher) would have been able to predict each of these in sufficient time to alert the frightened masses is a statistical impossibility, given that only six stones would be in play and that only three locations, namely Aubrey holes 51, 56, and 5, supposedly triggered the actual event. In other words, in any given 56-year cycle, a maximum of 18 forecasts would be possible, leaving in the above illustration, as many as 25 eclipses unaccounted for. Even if we write-off all of the solar eclipses – which are so erratic they would have been impossible for any early sky-watcher to predict -- that would have left at least 5 lunar eclipses with no predictive mechanism in place to warn of their coming. The net result would have been a sky-watcher with a success rate of about 42% -- and very little prospect of keeping his head for very long!

The Results

By starting in -1554 BCE with a white stone positioned at Aubrey hole 56, Hawkins had already set the stage for the first celestial event – a situation he described as "the year of that appalling spectacle, a winter eclipse" (page 141). It is the morning of January 14th -- just eight days after the winter solstice, which in that year had taken place of January 6th. The moon had risen at an azimuth of 128º 17' at 7:55 AM, to be followed 25 minutes later by the sunrise at an azimuth of 127º 09'. In other words, relative to the Aubrey holes, both the moon and the sun had risen, not over the Heel stone or either stones D or F behind Aubrey hole number 56, but 12 holes away from it – at a position characteristic of a lunar minimum instead. Although the sun ‘pursued’ the moon all morning long, it did not overtake it before both of them set 20 minutes apart shortly after noon. Thus, the “appalling spectacle of a winter eclipse” that Hawkins assumed to have begun his experiment, was *not visible* from Stonehenge because it did not culminate until 9:38 PM that evening – more than nine hours after both the sun and moon had dipped below the horizon.

But the ironies do not end there. A second solar eclipse took place in the year -1554 which *was* visible at Stonehenge, but Hawkins makes no mention of it. That event took place on July 11th, or four days after the summer solstice in that year. The moon rose at 3:37 AM that morning at an azimuth of 51º 28’, followed by the sun just 9 minutes later at an azimuth of 49ª 17, and just before 1 PM the eclipse reached its culmination. In this instance, both the moon and the sun had first appeared right behind Aubrey hole 56 and directly in line with the Heel Stone! Not an “appalling winter eclipse” to be sure, but what would have been “a most welcome summer eclipse” had Hawkins been aware of it.

Obviously, with no real way to anticipate the occurrence of the solar eclipses, he had failed to realize that the first one would be invisible from Stonehenge, while he may have simply disregarded the second because it took place near *mid-summer* rather than *mid-winter*. In any case, if he was to begin his 56-year count in the year -1554, he had only one opportunity left, and that was at the time of the full moon nearest the winter solstice. That took place on December 21st, with the moonrise at 4:32 PM at an azimuth of 50º 51’, or directly in line with Aubrey hole 56 and the Heel Stone. Unfortunately, it too, failed to produce an ‘appalling winter eclipse’ -- such as he had forecast for the solar eclipse of the preceding January -- but at least it did give him a fixed point from which he could initiate his count of the years. The Julian Day number for that date was 1153814. (Editor’s note: The Julian day count was the idea of a Dutch astronomer named Joseph Scaliger who devised it in the year 1583. Using Monday, January 1, 4713 B.C. as his starting date, it was designed to simplify astronomical calculations by providing a continuous running count of days; thus, finding the interval between such events as eclipses was essentially reduced to subtracting one Julian date from another. Interestingly, in Mesoamerica a similar idea (known as the ‘Long Count’) was initiated as early as September 18, -236 by the Zoques, who were responsible for the earliest calendrical studies in the New World. The Long Count was later adopted from them to good advantage by the Maya, who subsequently rose to the pinnacle of Native American astronomical achievement.)

As Hawkins continued his experiment, the following year brought the white stone to Aubrey hole 55 – which he termed a “safe hole”, because “nothing spectacular happens that year” (page 141). What he meant by “spectacular” is difficult to imagine, but what we do know is that three more eclipses, all of them visible at Stonehenge, took place in that year. The first two were solar eclipses, on June 30th and November 25th respectively, and the third was a lunar eclipse on December 9th.

On the morning of June 30, -1553, the moon rose at an azimuth of 51º 34’ at 3: 32 AM and the sun came up 13 minutes later at azimuth 49º 44’ – both again in line with Aubrey hole 56 and the Heel Stone. The eclipse culminated at 4:10 PM that afternoon. On November 25th, -1553, the moon rose at an azimuth of 114º 08’ at 7:03 AM and the sun followed 24 minutes later at an azimuth of 117º 45’; again, both alignments were typical of a lunar minimum, with the eclipse that afternoon reaching its culmination at 2:10 PM. In contrast, the lunar eclipse that culminated at 11:10 PM on the evening of December 9th, - 1553 was preceded by the moon’s rising at 4:03 PM at an azimuth of 56º 57’, in close alignment to stone F. Thus, rather than having been “a safe hole”, as Hawkins described it, Aubrey hole number 55 turned out to have been much more “spectacular” than he could have imagined.

Going on with his test of the “Stonehenge machine”, as Hawkins termed it, he next writes that “Actually nothing spectacular will happen for five years until the white stone is at Aubrey hole 51. Then, what does the computer predict? It is the year -1549 B.C. The winter moon reaches its extreme declination of +29º. It rises over D-center, it sets along 94-91 and in the moonset trilithon”. (Editor’s note: ‘94-91’ is a reference to an alignment between two stones outside the ring of Aubrey holes that Hawkins had identified as paralleling the track of the moon at its northern extreme. The ‘moonset trilithon’ is one of the post and lintel ‘arches’ of Stonehenge that is oriented to the midwinter moonset position at an azimuth of ca. 320º.)

The evening before the winter solstice in -1549 (January 5th), the moon rose at 4:08 PM at an azimuth of 41º 42’, in other words, right over stone D. During the preceding five years, the moon had gradually shifted its rising azimuth from the Heel Stone approximately 10º northward to its maximum declination, marked against the horizon by stone D. The Julian date for this event was 1155290, meaning that since Hawkins had begun his test on the 21st of December -1554, 1476 days had passed – an interval that is exactly equivalent to 50 lunations (i.e., full moons).

Actually, there were two eclipses in the year -1549, both of them lunar events. The first took place on April 3rd and was in progress as the moon rose that evening at 6:19 PM. Unfortunately, it did not rise over the center of stone D, as Hawkins reports, but at an azimuth of 89º 52' instead, once again in line with the equinox eclipses. Fifteen days later a solar eclipse took place after both the moon and sun had set, and was therefore not visible at Stonehenge. The second lunar eclipse occurred on September 28th, with the moon rising at an azimuth of 90º 46' at 6:31 PM and moving into the Earth's shadow later that night ca. 3:20 AM. The eclipse was still in progress as the moon set the following morning at 5:43 AM. Again, there was no moonrise over 'the center of stone D" but once again, a characteristic equinoctial event that took place about 50 degrees, or 7 Aubrey holes to the southeast of it.

Hawkins' account continues: "Four more years of safety pass by, then we come to 1545." (Editor's note: Somehow, in the interim, Hawkins missed another lunar eclipse on March 22, -1548.) "A black stone is now at 56. All the moon events and dangers of 1554 are repeated – predicted by the occurrence of that computer stone at Aubrey hole 56. In essence, a black or white stone at hole 56 occurs at intervals of 9, 9, 10, 9, 9, 10 years. This predicts the heel stone moon events. A white stone is at hole 51 at intervals of 18, 19, 19 years, predicting conditions of the high moon at +29º. A white stone is at hole 5 at intervals of 19, 19, 18 years, predicting the events associated with the low moon at +19º."

Unfortunately, at this point Hawkins' detailed year-by-year account of the test of his theory of eclipse prediction ceases, and he digresses to demonstrate how Stonehenge might be used to predict the modern dates of Easter, Passover, and Christmas instead. Perhaps this is just as well, for up to this point, his track record of eclipse prediction has not been very convincing. The "appalling winter eclipse" of -1554 turned out not to have been visible from Stonehenge at all, and the three eclipses that occurred in the year -1553 he dismissed as not having been 'spectacular' enough to even record. The moonrises he forecast over the center of stone D for both of the lunar eclipses of -1549 took place more than 50º away, and the lunar eclipse of March -1548 he overlooked entirely. Naturally, recording a series of failures certainly does not help to prove his point, nor does it make for particularly 'good reading'. So Hawkins abruptly "declares victory" – "Stonehenge scored 100 percent in predicting winter and/or summer eclipses" (page 178) – and changes the subject. Therefore, from here on, we are obliged to "fill in the blanks" with data derived both from the NASA Eclipse Website and the "Voyager" computer program produced by Carina Software of San Leandro, California.

Checking the NASA data, we find that a lunar eclipse took place on January 21, -1545. The moon had risen at 4:45 PM at an azimuth of 54º52', essentially in line with the Heel Stone. On July 16th, a second lunar eclipse had occurred, this one following a moonrise at 8:30 PM at an azimuth of 127º 30', close to the mid-point of the lunar minima. Finally, on the 11th of December, the winter moon rose at 3:48 PM at an azimuth of 50º 42', this time directly behind Aubrey hole #56. At this juncture, the Julian Day number tallied 1157091, revealing that another 1801 days had passed since Hawkins had commenced his test. Because this interval is equivalent to 61 lunations, this meant that the moon had taken no less than 111 lunations to move from the Heel Stone to stone D and then back again to the Heel Stone.

Again, just over four more years pass by, and the rising moon gradually shifts southward, arriving at an azimuth of 59º 41' on December 27th -1541. (Editor's note: Although Hawkins was no longer keeping track of eclipses at this point, in the interim two further solar eclipses had taken place: one on June 20, -1544, and another on December 4, -1543.) The moon has now reached stone F, and the Julian Day number is 1158568. Since it last left the Heel stone, another 1477 days have gone by, once again totaling 50 lunations. Now the moon begins its return toward the north, arriving at the Heel stone 1831 days later on December 31st -1536; since this leg of its journey took the equivalent of 62 lunations, we find that the moon's full round trip between the Heel stone and stone F has taken 112 lunations in all. Thus, when we sum up both of the moon's 'migrations' to and from the Heel stone, first to stone D and then to stone F, they total 223 lunations, which is the precise length of a saros, or 6585.3 days. A saros is a major lunar cycle, first discovered and named by the ancient Sumerians, for whom it meant "to repeat". Once a saros has been completed, the moon will begin repeating the same pattern of movements that it made during the past 18.61 years – but about eight hours later in the day. The reason for this is that extra fraction of three-tenths of a day; on a rotating Earth, that equates to a difference of about 120º of longitude when you're in the Tropics or low latitudes, so while any given place in these areas can expect to see a lunar pattern repeated twice, by the third time, a whole day will have passed and the next round of events will be out of sight. At higher latitudes, such as where Stonehenge is located, the period of visibility may extend to 5 or 6 occasions before the eclipse is no longer seen. In any case, if the ancient astronomers of Stonehenge had not learned the length of the saros by diffusion from the cultures of the eastern Mediterranean, they had certainly discovered it on their own by observing the moon's peregrinations back and forth between the companion monuments they had erected of either side of the Heel Stone.

It is also apparent that, just twelve lunations later, when their count of full moons reached the grand total of 235, they happened onto another astronomical cycle of special importance, this time regarding solar eclipses. In that interval – which now totaled 6939 days -- they found that exactly 19 years had also passed. (The true length of a year is 365.2422 days, rather than the length of 365.25 days assigned to it by Julius Caesar.) This meant that, in any given year, solar eclipses would be repeated on the same calendar dates on which they took place 19 years earlier. In fact, one of the earliest bits of information ever recorded about the ancient astronomer-priests of Stonehenge – reported by the Greek historian Diodorus in the first century BCE – was the special importance of a ritual that they performed every 19 years – an obvious reference to their knowledge of this fundamental relationship as early as two millennia ago.

At this point, let us pause to make an observation: if counting really was the function of the Aubrey holes, might not they have been used to count lunations just at well as years? Surely, Hawkins' suggestion that their number – 56 – is the most accurate measure of the lunar cycle is a highly creditable explanation of what *one* of their purposes may have been. But, by the same token, 56 would also have been the smallest common denominator to conveniently tally the number of lunations in the moon's 'migrations' back and forth between the Heel Stone and stones D and F, the first of which totaled 111, or one less than two rounds of the Aubrey circle, and the second that totaled 112, which equals exactly two rounds of the Aubrey circle. Carrying the count a dozen more Aubrey holes around the circle would have marked the completion of a Metonic cycle of 19-years as well. Thus, if Stonehenge was indeed a Neolithic computer, as Hawkins argued it was, and its primary function was counting, then its modular base of 56 would have made it ideally suited to serve as more than a “single-purpose machine” -- as the computer science student who Hawkins quoted on page 144 had scornfully described it. Not only could it have neatly kept track of the 56 years of a lunar cycle but also the four rounds that comprised a saros, as well as the nearly four and a quarter rounds that defined a Metonic cycle of 19 years. Thus, the marvelous “Stonehenge machine” whose complex astronomic alignments and functions Hawkins had first laid bare in 1965 may indeed have been more impressive than he could have imagined: in other words, the concept of multi-tasking might be much older than we thought!

Using Lunations to Predict Lunar Eclipses

During the 56-year period that Hawkins chose to use in demonstrating his theory of eclipse prediction, we know that at least three saroses had taken place, the first beginning on December 21, -1554 when the moon rose just behind the Heel Stone at an azimuth of 50º51’ – on Julian Day # 1153814. After that date, the first lunar eclipse that was visible at Stonehenge occurred on December 9, -1553 (Julian Day # 1154167). This means that a total of 353 days, or 12 lunations, had taken place in the interim; the NASA Web site identifies this as a total eclipse of a saros series labeled #10. It is interesting that this particular series had begun on June 17, -2454, so it had already been in existence for some 900 years and still had about four hundred more years to continue before it disappeared from the heavens. (As was pointed out earlier, it was one of the first ‘casualties’ of Hawkins’ theory, in not having been foreseen at all.)

The second lunar eclipse that occurred following Hawkins’ starting date took place on April 3, -1549 (Julian day # 1155378, a further 1211 days or 41 lunations along in time. We had now reached lunation #53 and in progress was a partial eclipse of saros series #7. This series had begun back in -2595, and still had a good 500 years ahead of it before it too, would disappear. Again, this was one of the eclipses that Hawkins had unfortunately missed with his stones in the Aubrey holes; he had predicted the moon would rise over the center of stone D – marking the northernmost latitude of the moon – but it rose instead along the azimuth that marked the solstices, vitiating his basic premise in the process.

The next year, -1548, a total eclipse of the moon in a saros numbered 17 occurred at lunation #65, an event that Hawkins also missed, as we have already noted. (Editor's note: saros series #17 began in -2089 and continued to -809, so the sky-watchers at Stonehenge had more than ample time to become accustomed to its appearance.) By the next time a lunar eclipse was visible at Stonehenge – on May 15, -1542 – Hawkins had abandoned his count. On this occasion there was a partial eclipse of the moon in saros series #6, and it was followed just under a year later (i.e., 12 lunations afterwards) by a total eclipse of the moon in saros series #16 – the final lunar event in the first saros cycle that Hawkins had set out to explore. (Editor's note: Saros series #6 began in the year -2624 and continued to -1071, whereas Saros series #16 began in -2172 and terminated in -874, both again affording the astronomers of Stonehenge ample opportunity to acquaint themselves with their patterns of recurrences.)

By this point, it should be clear to the reader that Hawkins' theory of eclipse prediction was not a sound one, and that even though the sky-watchers of Stonehenge had no catalog of saros numbers, they could recognize the return of a given series by the number of lunations by which it followed a fixed calendar date – primarily the sun's and the moon's relationship to the Heel Stone. Inasmuch as most of the saros series had their origins well in advance of the date chosen for Hawkins' experiment, any time an eclipse took place other than at a known lunation, the astronomers of Stonehenge would have made sure to add it to their roster in anticipation of its return, the moral being "overkill" rather than "overlook". In this manner, it is likely that most of the 'surprises' in their predictive experience had long since been put to rest before the period which we have discussed at length in this paper.

The pattern of the eclipses visible at Stonehenge during the two saros periods preceding Hawkin's test period, and the three that took place during the 56-year span he had intended to study are shown in Table 1 below. The lunations are measured from the Julian Dates at the top of each column which mark the moon's rising position over the Heel Stone, and each eclipse is identified by its saros number and classified as to its character: either total (T) or partial (P).

Table 1. Five Saros Periods at Stonehenge, -1590 to -1500.

Lunations	Saroses from -1590 to -1572	Saroses from -1572 to -1554	Saroses from -1554 to -1536	Saroses from -1536 to -1518	Saroses from -1518 to -1500
0	JD# 1140644	JD# 1147229	JD# 1153814	JD# 1160399	JD# 1166984
12	10-T	10-T	10-T	10-T	10-T
18	15-T	15-P	15-T	15-T	15-T
53	7-T	7-T	7-P	7-P	
59	12-T	12-T	12-T	12-T	12-T
65	17-P	17-P	17-T		
71	22-T		22-T	22-T	22-T
100			9-P	9-T	9-T
106				14-T	14-T
141		6-P	6-P	6-P	
147				11-T	11-T
153	16-T	16-T	16-T		
188	8-T	8-T		8-T	8-T
194	13-T			13-T	13-T
206	23-T			23-T	23-T

(Compiled from data published on NASA Eclipse Website.)

An interesting observation may be made from the above table, namely that exactly 12 lunations after the completion of a given saros series consisting of 223 lunations, the completion of a Metonic cycle measuring 235 lunations, or precisely 19 years, was ‘automatically’ revealed by the eclipse in saros series #10 that followed it. Of course, what we don’t know is which of the particular dates the sky-watchers of Stonehenge hit upon to serve as the initiation of the ritual 19-year count that Diodorus mentions in the first century BCE. However, an analysis of even the five saros periods listed above may provide some possible clues in helping to answer this question. For example, on November 18, -1589, the moon rose at 4:45 PM at an azimuth of 61º34’, or directly in line with stone F. The eclipse that evening culminated at 23:37 hours local time. The next eclipse in the saros #10 series took place on November 28, -1571, and was actually in progress as the moon rose, and reached its culmination at 7:38 hours local time, or almost exactly 8 hours later as expected. When saros #10 next reappeared on December 9, -1553, the eclipse again culminated exactly 8 hours later in the day, at 15:38 local time. On its fourth recurrence, the date was now December 20, -1535, the moon had risen over the Heel Stone at 4:14 PM, the eclipse reached its maximum just five minutes shy of it peak three occasions earlier, i.e., at 23:32 hours, and was still in progress when the moon set. Thus, in the course of just four saroses, the date of the #10 eclipse had shifted about a month later in the calendar year, namely from November 18 to December 20. Yet, it was precisely during the period examined above that saros #10 was in the very midst of a 415-year run of total eclipses, which accounts for its dependable appearance in all of the years cited. During that phenomenal length of time, the date of the saros #10 eclipse shifted from early June (the 9th) to the middle of the following February (the 13th) – more than a total of 8 months. However, Diodorus' account of the celebration of the 19-year cycle explicitly mentions that "the visiting god of Apollo both plays on the cithara and dances continuously the night through from the vernal equinox to the rising of the Pleiades", suggesting that only a single night separated the two events. While today we would have to look to a time-frame that would start on or about March 21, at the time at which Diodorus wrote, the date would have been 2 days later according to the Julian calendar. However, the faintness of the stars that comprise the Pleiades would have precluded the observation of its rise in a sky that was not reasonably dark, so it is unlikely that they could have been sighted unless they rose at least about a half hour before sunrise, a situation that favors an earlier date rather than a later one, as can be seen from Table 2 below. On the other hand, because the difference in azimuths of the rising points of the sun and the Pleiades were little more than 3° apart some 4500 years ago, they have steadily increased as time went by, and the visibility of the latter's rising may have gradually improved to some degree for that reason alone. In Table 2, a comparison is made of the dates of the vernal equinox followed by the rise of the Pleiades a day later during the period from the year -2500 to 0. Because at the time that Diodorus wrote, it would have been difficult if not impossible to see the rising of the Pleiades, the "hard facts of astronomy" strongly suggest that the origins of this ritual most likely must be traced to a time about two millennia earlier, i.e. somewhere between -2500 and -2000 BCE – or just about the time that the first wave of Megalithic sea farers probably reached Britain. (Editor's note: It should be recalled that, at the equinoxes the sun rises and sets at a right angle to the meridian, an observation that would certainly not have gone missing to a Megalithic sky-watcher. This means at Stonehenge, it rose over Aubrey hole #6 and set over Aubrey hole #34, the meridian having been defined by Aubrey holes #20 and #48.)

Table 2. A Comparison Between the Rising Times of the Pleiades and the Sun from -2500 to 0.

Year	*Date of Vernal Equinox – Azm.*	*Date of Pleiades Rise - Azimuth*	*Time of Pleiades Rise (Alcyone)*	*Time of Sun Rise*
-2500	April 12 – 88º	April 13 – 85º	5:35 AM	6:06 AM
-2000	April 8 – 88º	April 9 – 81º	5:47 AM	6:06 AM
-1500	April 4 – 88º	April 5 – 76º	5:59 AM	6:06 AM
-1000	March 31 – 88º	April 1 – 71º	6:10 AM	6:06 AM
-500	March 27 – 88º	March 28 – 67º	6:22 AM	6:06 AM
0	March 23 – 88º	March 24 – 63º	6:35 AM	6:06 AM

(Compiled from the Voyager Computer Program, Version 1.2, Carina Software, San Leandro, CA 94577. Note that the rising time cited for the Pleiades is actually that of Alcyone, its brightest star.)

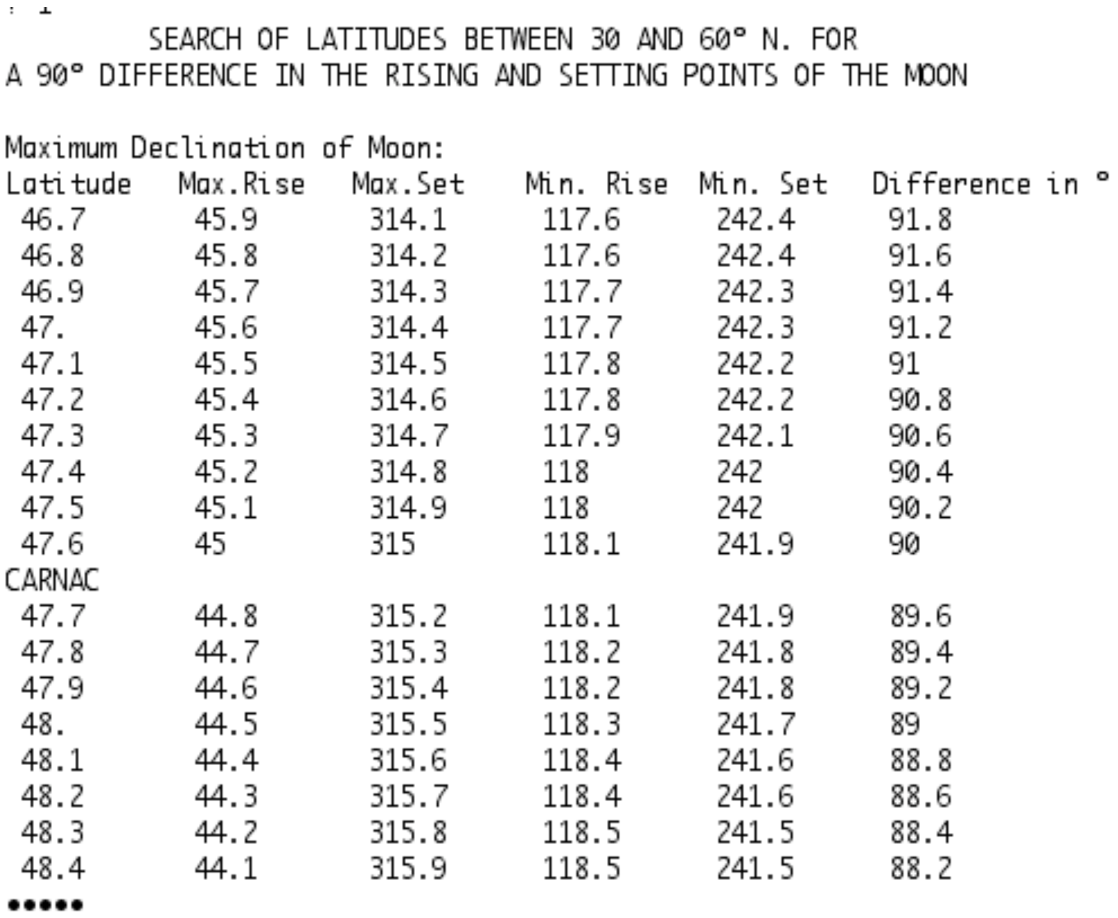
The Special Place of Stonehenge in Megalithic Society

Although there is no question but that Stonehenge is the “crown jewel” of Megalithic sites dedicated to astronomy, it is only one of five such monuments scattered over Western Europe. All five of them share a distinctive unifying characteristic, namely that they each demonstrate a right-angle relationship to a specific astronomic function. If we accept the notion that the Megalithic culture had its origins in the Eastern Mediterranean, then the first such specialized monument that they constructed using this ‘principle’ was at Carnac, on the south coast of the Brittany Peninsula in France. There the monument took the form of multiple rows of mammoth stones, most of them weighing three tons or more, extending inland from the coast for several kilometers. Altogether, the construction of the monument must have involved the movement and erection of at least 2,500 to 3,500 tons of stone, most of which could have been assembled using water-transport, apart from the last few kilometers.

As such, Carnac must qualify as the most ambitious endeavor ever undertaken by Megalithic man, and one whose motivation can only be explained in terms of commemorating a location deemed by their priest-astronomers as a site of extraordinary importance. Carnac happens to be situated at the only latitude in the northern hemisphere where a right-angle exists between the rising and setting points of the moon at its maximum declination, i.e., the farthest north point it reaches in its 18.61 year 'migration' from one extreme to another. (See Table 3 below.) While we do not know what significance the Megalithic sky-watchers attached to this particular relationship, we do know that circles divided into four 90º quarters show up frequently in late Stone Age and early Bronze Age art. It would seem that the only astronomic use of such a relationship is that it provides the sole manner for ascertaining in advance where the moon will rise on the next occasion. Because the moon seemingly 'bounces' haphazardly around the sky from one night to the next, by tracing its course across the heavens until it set and then extending a straight line to the eastern horizon, the Megalithic sky-watchers could obtain a close approximation of where it would rise on the following evening. At Carnac, the 'magic' of the right angle defined both the rising and setting azimuth of the moon at its farthest northern remove, and since the Megalithic navigators were advancing in that direction themselves, those were no doubt the principal lunar positions they were interested in. Moveover, on the Brittany Peninsula, with the open sea to the south, there were no azimuths in that direction against which that they could 'fix' the moon in any case.

'

Table 3



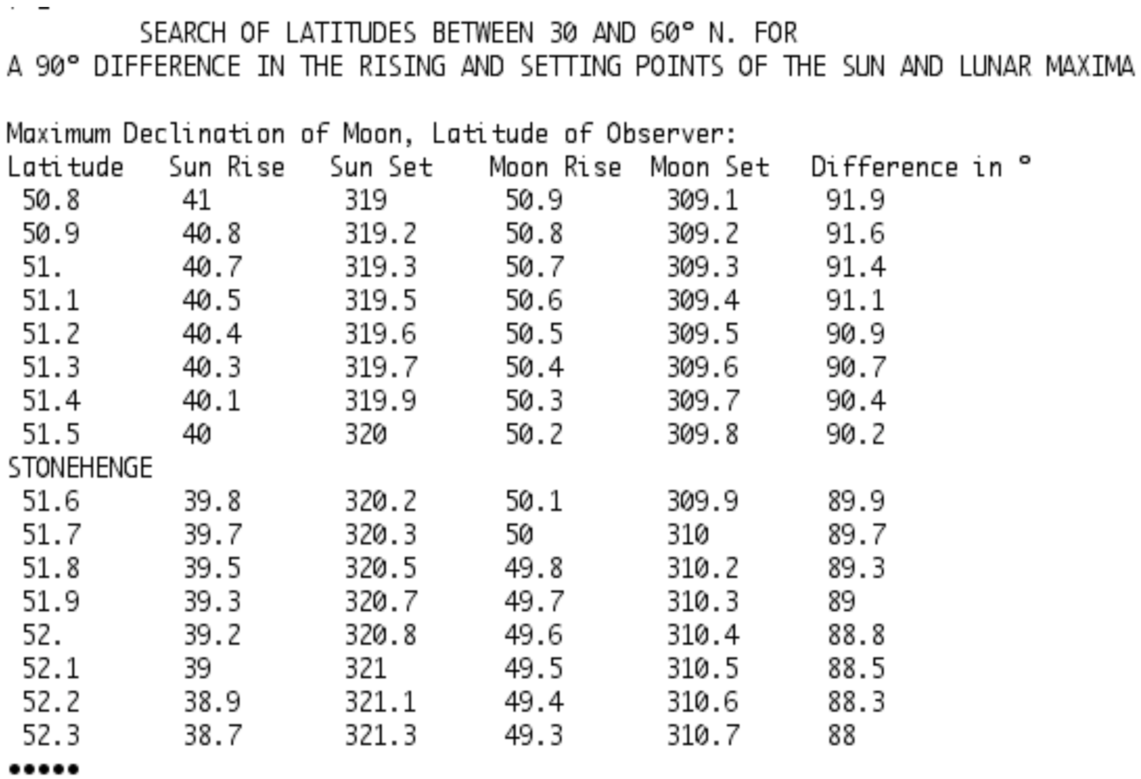
```
        SEARCH OF LATITUDES BETWEEN 30 AND 60° N. FOR
A 90° DIFFERENCE IN THE RISING AND SETTING POINTS OF THE MOON

Maximum Declination of Moon:
Latitude   Max.Rise   Max.Set    Min. Rise  Min. Set   Difference in °
 46.7       45.9       314.1      117.6      242.4      91.8
 46.8       45.8       314.2      117.6      242.4      91.6
 46.9       45.7       314.3      117.7      242.3      91.4
 47.        45.6       314.4      117.7      242.3      91.2
 47.1       45.5       314.5      117.8      242.2      91
 47.2       45.4       314.6      117.8      242.2      90.8
 47.3       45.3       314.7      117.9      242.1      90.6
 47.4       45.2       314.8      118        242        90.4
 47.5       45.1       314.9      118        242        90.2
 47.6       45         315        118.1      241.9      90
CARNAC
 47.7       44.8       315.2      118.1      241.9      89.6
 47.8       44.7       315.3      118.2      241.8      89.4
 47.9       44.6       315.4      118.2      241.8      89.2
 48.        44.5       315.5      118.3      241.7      89
 48.1       44.4       315.6      118.4      241.6      88.8
 48.2       44.3       315.7      118.4      241.6      88.6
 48.3       44.2       315.8      118.5      241.5      88.4
 48.4       44.1       315.9      118.5      241.5      88.2
•••••
```

(Note that in each of Tables 3 through 6 the 'optimal' latitude for locating a right angle between the specified astronomical relationships is designated by the name of the place in question. This does not mean that the latitude cited exactly matches that of the place named, but rather how close to the 'optimal' latitude the exigencies of site location permitted the Megalithic sky-watchers to build their monument and still satisfy the principle they were trying to demonstrate. Carnac, located immediately on the coast, is seen to have satisfied the 'optimal' location perfectly.)

However, when they reached the Salisbury Plain of Southern England, they made an even more intriguing discovery: namely, that at the latitude of Stonehenge, a right angle existed between the northern limit of both the rising of the sun and the setting of the moon. (See Table 4 below.) No wonder they might have believed that this 'special relationship' would be useful – perhaps even critical -- in their efforts to predict eclipses; certainly, this notion was also implicit in Hawkins' theory that he had decoded the function of Stonehenge by linking the azimuth of the mid-winter moonrise to the pattern of eclipses during the following year. However, in the analysis just concluded, we have found that the real key to eclipse prediction at Stonehenge was in the counting mechanism afforded by the Aubrey holes, not for 18.61-year lunar cycles as Hawkins supposed, but for the number of lunations that occurred after a fixed point in the calendar – such as the sunrise over the Heel Stone. For a preliterate people, the Aubrey holes provided a means of recording not only lunations with which to predict eclipses, but also the duration of saroses, and a precise measure of the true length of the year as well.

Table 4



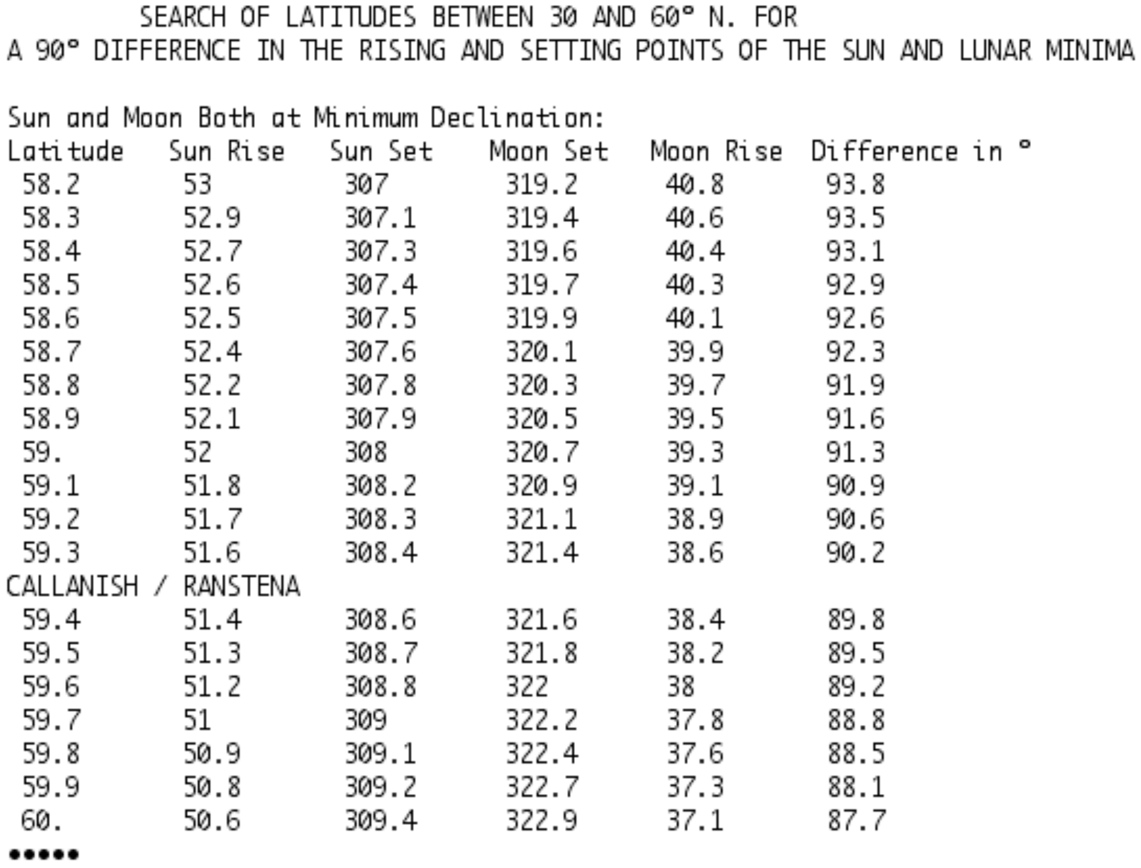
```
       SEARCH OF LATITUDES BETWEEN 30 AND 60° N. FOR
A 90° DIFFERENCE IN THE RISING AND SETTING POINTS OF THE SUN AND LUNAR MAXIMA

Maximum Declination of Moon, Latitude of Observer:
Latitude   Sun Rise   Sun Set    Moon Rise  Moon Set   Difference in °
 50.8      41         319        50.9       309.1       91.9
 50.9      40.8       319.2      50.8       309.2       91.6
 51.       40.7       319.3      50.7       309.3       91.4
 51.1      40.5       319.5      50.6       309.4       91.1
 51.2      40.4       319.6      50.5       309.5       90.9
 51.3      40.3       319.7      50.4       309.6       90.7
 51.4      40.1       319.9      50.3       309.7       90.4
 51.5      40         320        50.2       309.8       90.2
STONEHENGE
 51.6      39.8       320.2      50.1       309.9       89.9
 51.7      39.7       320.3      50         310         89.7
 51.8      39.5       320.5      49.8       310.2       89.3
 51.9      39.3       320.7      49.7       310.3       89
 52.       39.2       320.8      49.6       310.4       88.8
 52.1      39         321        49.5       310.5       88.5
 52.2      38.9       321.1      49.4       310.6       88.3
 52.3      38.7       321.3      49.3       310.7       88
•••••
```

(Note that the ‘optimal’ location for Stonehenge no doubt should have been 0.3 degree farther north, but the River Avon, that was most likely used to transport some of the larger stones that came from South Wales, was probably not as navigable above Durrington Walls as it was in its lower course, so the present location served as a ‘tolerable’ compromise.)

Continuing their advance northward between the islands of Britain and Ireland, the Megalithic seafarers rounded the outer edges of the Hebrides before turning east along the northern coast of Scotland. It was on the island of Lewis that they discovered a third astronomical relationship, and that must have proved somewhat disquieting to them. At the site which is now known to us as Callanish, they observed that a right angle existed between the *extreme southern rising point of the moon* and the *extreme southern setting point of the sun*, in other words, just the reverse situation that obtained at Stonehenge. (See Table 5 below.) While this in itself was not so disquieting, at the same time they realized that the moon was now so low in the sky that were they to continue much farther to the north, they would lose sight of it entirely during the summer, and to no longer have the comfort of moonlight during the night must have suggested to them that they were nearing the very edge of the habitable world. This may explain why they only hesitantly seemed to have ventured into the latitudes of Norway and instead headed directly east across the North Sea to settle next in what are today Denmark and Sweden.

Table 5



```
        SEARCH OF LATITUDES BETWEEN 30 AND 60° N. FOR
A 90° DIFFERENCE IN THE RISING AND SETTING POINTS OF THE SUN AND LUNAR MINIMA

Sun and Moon Both at Minimum Declination:
Latitude   Sun Rise   Sun Set    Moon Set   Moon Rise  Difference in °
 58.2       53         307        319.2      40.8       93.8
 58.3       52.9       307.1      319.4      40.6       93.5
 58.4       52.7       307.3      319.6      40.4       93.1
 58.5       52.6       307.4      319.7      40.3       92.9
 58.6       52.5       307.5      319.9      40.1       92.6
 58.7       52.4       307.6      320.1      39.9       92.3
 58.8       52.2       307.8      320.3      39.7       91.9
 58.9       52.1       307.9      320.5      39.5       91.6
 59.        52         308        320.7      39.3       91.3
 59.1       51.8       308.2      320.9      39.1       90.9
 59.2       51.7       308.3      321.1      38.9       90.6
 59.3       51.6       308.4      321.4      38.6       90.2
CALLANISH / RANSTENA
 59.4       51.4       308.6      321.6      38.4       89.8
 59.5       51.3       308.7      321.8      38.2       89.5
 59.6       51.2       308.8      322        38         89.2
 59.7       51         309        322.2      37.8       88.8
 59.8       50.9       309.1      322.4      37.6       88.5
 59.9       50.8       309.2      322.7      37.3       88.1
 60.        50.6       309.4      322.9      37.1       87.7
•••••
```

(The sites of both Callanish and Ranstena represented the greatest compromises between the ‘optimal’ latitude and what was ‘possible’ in response to the constraints imposed by the local geography. Callanish would ‘ideally’ have been located 1.1 degree farther north, but then it would not have lined up with the winter solstice sunset over Tirga Mor, nor would the sighting of the mid-summer moon have been possible in certain years.

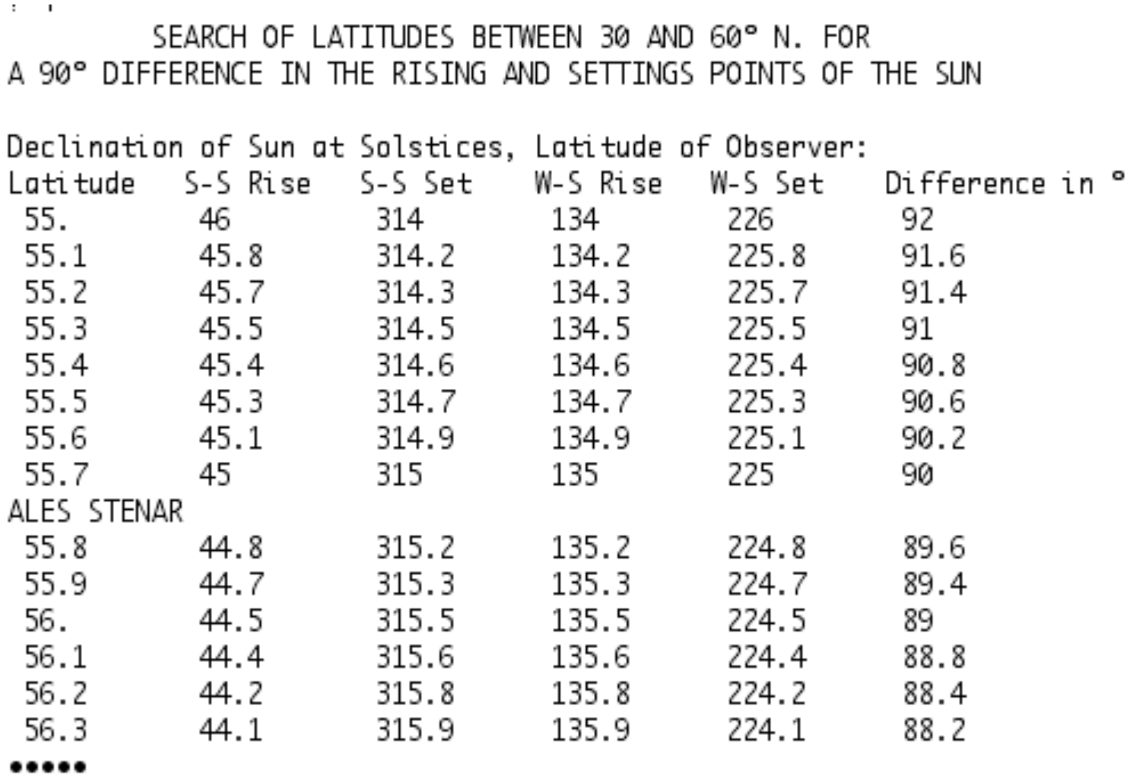
Ranstena, a further 0.3 degree to the north, lies that much closer to the ‘optimal’ latitude for a right angle alignment between solar and lunar minima, but its site was largely dictated by its proximity to the River Tidan. Its mammoth stones could only have come from a geologic formation to the east, floated on rafts down the river to within 1 kilometer of its site, and dragged into their present position from there. The informational placard at the monument suggests that the stones were moved more than three kilometers over a clay lake plain to the west, but this is quite unlikely because the geology changes abruptly in this direction and no stones of the type represented in the monument are found anywhere in this region.)

As an agriculturally based society, it is obvious that they were much happier to land in Denmark than they were in Sweden, because ultimately their settlements there contained probably twenty times the number of inhabitants that eventually established toe-holds in western coastal Sweden. Yet, even in Denmark they very consciously avoided the sandy outwash plains of the western peninsula of Jutland and gravitated instead to the lime-rich moraines, both in Jutland and on the islands to the east. In Sweden, once they had made their bridgehead on the rocky west coast, they quickly pressed inland until they encountered the lime-rich plains of both the West Gothic Plain in the central part of the country and the province of Skåne in the far south, and immediately began concentrating their major land-clearing activities in these more favored areas.

As they did so, they also erected their final two astronomical outposts in Sweden, duplicating Callanish at the very northern end of the West Gothic plain at a site known today as Ranstena, or “the stones of Rane” (See Table 5 above.), and founding a unique solar site in the very south of the country overlooking the Baltic Sea at a place called Ales Stenar, or “the stones of Ale”. (Editor’s note: Both Callanish and Ranstena are situated within 25 miles (40 km) of the same latitude and both were located using a mountain as the setting point of the sun at the winter solstice. These similarities strongly suggest that persons familiar with Callanish were involved with the siting of Ranstena. On the other hand, the monuments at both Ranstena and Ales Stenar have the outlines of ships constructed with mammoth blocks of stone, and are described as “ship settings” by Scandinavian archaeologists. That at Ranstena is composed of 24 stones, each of which weigh between 20 and 30 tons, making it the larger of the two monuments in total tonnage. Ales Stenar is composed of 59 stones whose combined weight totals something over 200 tons, but its more impressive length and its spectacular location have made it one of the most visited archaeological sites in all of

Sweden. Strangely, neither of these latter two sites has yet been recognized as Megalithic in origin by Swedish archaeologists, who attribute their construction to the Late Iron Age (i.e., 400-1100 AD), an era that began with the turmoil of the Germanic Migrations overrunning the Roman Empire and ended with the Scandinavian Vikings ravaging the coasts of medieval Western Europe for over 300 years. Although both of these unsettled times in history would have been sufficient cause to dissuade anyone from carrying out such massive ‘public works’ projects as these, in Sweden the ‘stylistic’ arguments offered by the archaeologists based on ‘the wider spacing of their stones’ continue to prevail over both solid astronomical evidence and common sense, in the process denying the country recognition of two of the most impressive Megalithic monuments in existence. (See Table 6 below.)

Table 6



```
        SEARCH OF LATITUDES BETWEEN 30 AND 60° N. FOR
A 90° DIFFERENCE IN THE RISING AND SETTINGS POINTS OF THE SUN

Declination of Sun at Solstices, Latitude of Observer:
Latitude   S-S Rise   S-S Set    W-S Rise   W-S Set    Difference in °
 55.        46         314        134        226        92
 55.1       45.8       314.2      134.2      225.8      91.6
 55.2       45.7       314.3      134.3      225.7      91.4
 55.3       45.5       314.5      134.5      225.5      91
 55.4       45.4       314.6      134.6      225.4      90.8
 55.5       45.3       314.7      134.7      225.3      90.6
 55.6       45.1       314.9      134.9      225.1      90.2
 55.7       45         315        135        225        90
ALES STENAR
 55.8       44.8       315.2      135.2      224.8      89.6
 55.9       44.7       315.3      135.3      224.7      89.4
 56.        44.5       315.5      135.5      224.5      89
 56.1       44.4       315.6      135.6      224.4      88.8
 56.2       44.2       315.8      135.8      224.2      88.4
 56.3       44.1       315.9      135.9      224.1      88.2
•••••
```

(The above table suggests that Ales Stenar, instead of being located at latitude 55.3º N., should have been located 0.4 degree farther north, but again the realities of its site preclude such astronomical ‘precision’. Moving over 200 tons of stone to the top of a 100-meter (328 ft.) moraine was an outstanding achievement in its own right; trying to drag them a further 40 km (25 mi.) into the interior would have been quite unnecessary, inasmuch as the difference in azimuth of 1º was well within the tolerance of naked eye sky-watchers, and in its present location this beautiful monument is an enduring testament to both the esthetic and scientific sensitivity of its ancient Megalithic builders.)

One final observation regarding the location of Ales Stenar: why was this solar site the last in the 'chain' of astronomical 'right angles' to be discovered? Certainly, the Megalithic seafarers had passed the latitude at which it is located when they were on their way northward between Ireland and Britain, so why did they miss it? The most likely explanation is that they would have just entered the North Channel, the narrowest place between the two islands, but likewise found themselves having to choose their way northward very carefully so as not to get lost in either one of the fingers of the Firth of Clyde or the Kilbrannan Sound that also opened in the same direction but dead-ended on the Scottish coast. Moreover, onshore this maze of waterways was bordered by ever more rugged terrain, making long distance sightings of the sun increasingly difficult as well.

References

Espenak, Fred and Jean Meuss, "NASA Eclipse Website". Initially established ca.1996 and since updated.

Hawkins, Gerald S. (in Collaboration with John B. White). "Stonehenge Decoded". Doubleday and Company, Garden City, New York. 1965.

Malmström, Vincent H. "Mistaken Identity: Have the Swedes 'Short-Changed' the 'Megaliths'?", "Collected Papers: 1950 to 2010", www.dartmouth.edu/~izapa

C.H. Oldfather. "Diodorus of Sicily". London: W. Heinemann LTD, 1933.

"Voyager" Computer Program (Version 1.2), Carina Software, San Leandro, California, 1988-89.